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AN ALTERNATIVE TO "SUPPRESSION": MODELING METHODOLOGY FOR ASSESSING INDIRECT EFFECTS OF WEAPONS AND HUMAN PERFORMANCE DEGRADATION

ADA W. DZIESZUK GILMAN

AUGUST 1990

U.S. ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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Performance of weapon systems and failure of well planned military operations can frequently be attributed to either a malfunction or limitation of the human element. Hence, an accurate quantification of weapons effects should include not only direct effects of weapons (physical destruction/degradation of targets and production of casualties) but also indirect effects. Most algorithms and equations used in military analysis today, however do not consider indirect effects of weapons. Traditionally, the notion of "suppression" has been cited in such a context. The subject of this report is the indirect and psychological effects of weapons. A proposal for modeling them is presented. The difficulties in human performance degradation modeling in the context of modern warfare are discussed. An argument challenging the validity of continued usage of the traditional term suppression is presented. A definition of indirect effects of weapons is offered; a taxonomy of the relevant combat phenomenon is established. A modeling proposal on the quantification of indirect effects is described involving the establishment of five submodels representing several distinct elements of combat system: Individual/Personnel, Visual Detection, Immediate Physical Threat (Firing), Communication, and Decision Making.

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1. INTRODUCTION

Weapon systems can be degraded and well planned military operations can fail as a result of either a malfunction or limitation of the human element. *All* operations are limited by the quality of human performance in every element of a battlefield system, such as firing, acquisition and surveillance of targets, maneuver/mobility, command and control, communication, and others. Therefore, the human operator is probably the most important source of system vulnerability.

These human limits imposed on technology compromise the effectiveness of today's sophisticated military hardware systems. On the other hand, exploitation of these limitations can enhance the impact of a victorious force which knowledgeably implements them as a part of its tactical and strategic planning. Nevertheless, personnel vulnerability factors and indirect effects of weapons are overlooked in most of the algorithms and equations used in military analysis today; they are viewed as difficult to quantify.

The mere presence of Napoleon on the battlefield was worth 40,000 men— is a famous statement attributed to both Wellington and Marshal Blucher (Dupuy, 1985). Regardless of the quantitative precision of this statement, it is indicative that combat cannot be accurately modeled in a wholly mechanistic manner.

1.1. BACKGROUND

Historically, the artillery has been known to produce the most significant indirect incapacitating effects versus physical destruction or degradation of targets. Dupuy (1989) notes that artillery inflicts about 50% of all casualties, yet only 1/3 of the actual lethal casualties directly relate to an artillery weapon's effect. The remaining fraction falls into the category of indirect effects of weapons. This phenomenon has often been described by the military analytical community as suppression.

Quoting the Battle Book of the Center for Army Tactics, Army Command and General Staff College, suppression of a target limits the freedom of enemy personnel in the target area. It causes tanks to button up and obscures the battlefield. It has a cumulative effect on the battlefield because it allows direct fire weapons to effectively place fires on targets. The effects of suppressive fires usually last only as long as the fires are continued. Most targets on the battlefield can be suppressed *(Battle Book*, 1986).

The human performance degradation issue is highly relevant in this context. Optimal performance of hardware can be compromised through non-physical damage to the crew. Nevertheless, these human factors have frequently been omitted from military combat models. As Van Nostrand (1986) states, although human participation and influence are pervasive in actual combat, the effects of human factors or human performance are frequently considered only implicitly, if at all, in combat models. Lack of data and modeling attention to human factors is seen by Thomas (1986) as one of the most serious problems in modeling today.

The human operator imposes limits on technology and his performance can be degraded under battlefield conditions, yet, as Howard and Lipsett (1976) relate, many of our present combat models assume that all human tasks are performed perfectly. The research on human reliability suggests that 50 percent or more of system failures may be traceable to human error (Howard, Lipsett, 1976). Van Nostrand, in her 1986 review of military modeling, reports that the physical and psychological limits of human capabilities suggest that the results of combat are as likely to be determined by human performance as by differences in equipment capabilities.

2. PROBLEM

2.1. WHY IS IT DIFFICULT TO MODEL HUMAN PERFORMANCE IN COMBAT?

The easiest aspects of combat to quantify are the direct effects of weapons. Weapons have well known and measurable physical characteristics; they obey the standard laws of physics and they are relatively predictable in their performance (at least theoretically) (Dupuy, 1985). However, there are also indirect effects of weapons which can cause performance degradation of any combat element. A soldier is highly susceptible to such influence which can reduce his ability to fight. Some of the reasons are listed below.

With the rapid development of modern technology, the human operator can be a limitation to a combat system. Human velocity (running) of 30 ft/sec, reaction times of 0.5 sec, and the instantaneous perception time of 0.05 sec, are far inferior to a weapon's physical speeds, such as velocity of light (2.99×10^8 m/sec) or speed of sound (1,087 ft/sec). Also, human sensory/perceptual and general information processing abilities are frequently inferior to the data/information processing speed of today's machines. This poses a challenge in design, training, and many other related factors regarding the human-machine interface as well as its modeling.

Furthermore, physical performance and human workload capabilities have limits. This becomes very apparent when operating in sustained/continuous operation scenarios. The soldier's performance degrades and his vulnerability increases as a result of fatigue, extreme temperatures, physiologic discomfort (e.g., lack of sleep, hunger), and other conditions which are typical of prolonged combat.

Combat is a highly complex phenomenon. Strangeness and unpredictability of the combat situation contribute to severe psychological threat and stress (Coleman et. al, 1976). Additionally, with the continual threat of injury or death and repeated narrow escapes, one's ordinary methods of coping are relatively useless. These factors lead to degradation of human performance and also to the display of atypical behaviors. If the problem is augmented by including a combatant's interpersonal and intrapersonal differences, not only does it become more difficult to identify and define those human factors precisely, but quantifying the decay of a soldier's fighting ability becomes even more difficult.

2.2. WHAT ARE DIRECT AND INDIRECT EFFECTS OF WEAPONS?

There are many physical, environmental, physiological, behavioral, and operational variables present in the battlefield environment, therefore, there are *numerous* indirect incapacitation mechanisms existing on the battlefield, not just one. *All* of the battlefield subsystems are vulnerable to the direct as well as indirect effects. Combat subsystem operations that are dependent on a human operator are particularly vulnerable to the indirect effects of weapons. These indirect effects of weapons can be as significant as direct effects and can have a substantial impact on unit effectiveness.

There is a relationship between the number and types of combat weapons and the number of casualties suffered by opposing sides. A completely accurate account of the relationship requires that both direct and indirect incapacitating effects be properly included.

The direct effects of weapons are any physical damage to any combat element, either personnel or materiel. They are caused by the action of kinetic energy penetrators, fragmentation, shaped jet charges, blast and overpressure, toxic gases, burns, or any other physical injury/damage mechanisms.

On the other hand, the indirect effects of weapons will be generally referred to in this report as any effect beyond physical damage which affects personnel. And these effects are the result of general combat stress, a near miss, or other related non-physical damage combat mechanisms.

Indirect weapons effects, related human factors in combat, and a proposal for modeling them is the subject of this report.

3. INDIRECT EFFECTS OF WEAPONS

The effectiveness, or *lethality*, of weapons, is traditionally regarded as a function of their ability to inflict physically measurable damage:

$$E_w = f(D)$$

where,
E_w = Weapon's Effect,
D = Damage.

The actual direct or physical damage effects of weapons, however, do not account fully for *all* the "damage" in combat. There are situations where a soldier is wounded (through small fragments, for example) but his combat performance is not adversely affected. On the other hand, there are also circumstances in which neither hardware/apparatus nor human operator is physically damaged but hardware or crew performance becomes impaired. Examples of such circumstances are a decrease in fire rate of an undamaged weapon operated by an unwounded soldier; or despite a lack of injury on the observer's part, there is a cessation of acquisition/ surveillance activities; or despite perfectly functioning communication equipment, a communication breakdown occurs. These are the results of non-physical damage and psychological impairment to the human operator which, in turn, causes performance degradation of the machine. In this report, as mentioned earlier, this mechanism will be referred to as indirect effects of weapons.

As shown in Figure 1, the direct effect of a weapon is physical damage or destruction of a target, either equipment and supplies or human. Direct damage is caused by kinetic energy penetrators, fragments, shaped charge jets, blast and overpressure, blunt injury and acceleration, toxic gases, burns, and others. Consequently, the direct effect on humans or the symptoms of these causes—would be penetrating wounds, fractures, burns, internal organ injuries, sensory impairments, or any other related effects.

On the other hand, the indirect effects of weapons do not result in physical damage but trigger degradation of various combat functions through such mechanisms as combat stress, or a near miss causing alteration in .. physical environment and thus contributing to crew sensory/perceptual disturbances, or others. Combat stress, resulting in a combat stress casualty, could cause the ***generalized*** degradation effect where ***any*** or ***all*** combat functions that a soldier performs are affected. The other causative mechanism, the near miss with its related factors, can cause function-specific performance degradation. That is, a ***specific*** sensory/perceptual or

cognitive impairment can degrade performance of *related* and *specific* combat functions. Examples are: a near miss that produces dust and smoke, obstructing the line of sight; or a near miss that causes a loud noise, masking a critical part of a message.

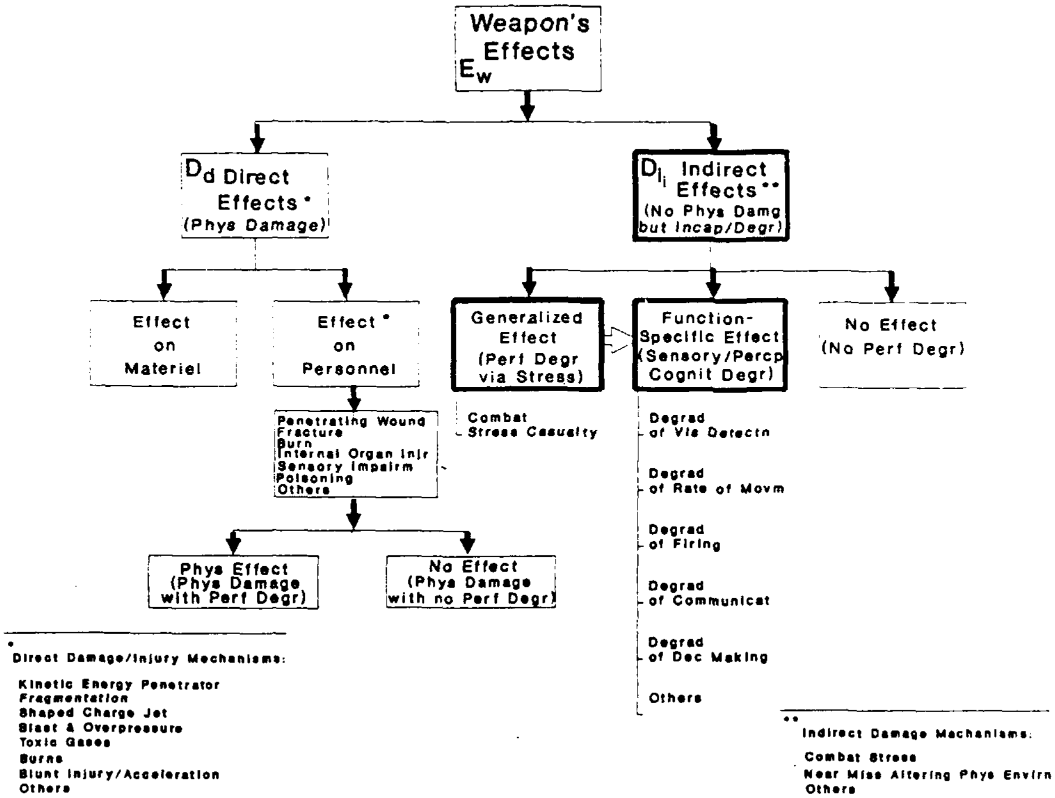


FIGURE 1. Direct and Indirect Effects of Weapons.

Since the indirect effects can seriously degrade the unit's capacity to fight, they should be considered in modeling the weapon's effectiveness along with the direct effects:

$$E_w = f(D_d, D_{i_i})$$

where,

E_w = Weapon's Effect
D_d = Weapon's Direct Damage Effect
D_{i_i} = Weapon's Indirect Incapacitating Effect of Type i

These indirect effects of weapons have an impact on unit effectiveness. Operational and tactical planners should consider them as these effects can be exploited for offensive as well as defensive situations.

3.1. IS COMBAT SUPPRESSION A CONCATENATION OF INDIRECT COMBAT EFFECTS?

In the military community, suppression is a popular term dealing with the other-than-direct weapons' effects. Traditionally, the term suppression can be regarded as a series of indirect effects of weapons, but is it? The military analytical community has struggled with this notion since the realization of indirect artillery effects. Many believe it is difficult if not impossible to measure and quantify this perplexing phenomenon. Some doubt its existence. Therefore, the remaining question is, what is the definition of suppression?

3.2. WHAT IS SUPPRESSION?

There is a variety of definitions of suppression available. However, a great deal of inconsistency and lack of uniformity exist in the numerous, perhaps too numerous, descriptions of this term. To illustrate it, the definitions of suppression from various sources will be presented.

3.2.1. Military Definitions

Examples of the definitions appearing in military literature follow:

1. Suppression, in its broadest sense, includes modification of a unit's performance due to (a) actual incapacitation from firepower, (b) behaviors intended to lessen the risk of incapacitation from firepower systems, and (c) confusion of senses from non-firepower systems (suppression of command and control activities with electronic warfare) (*Report,* 1975).

2. Suppression—Direct and indirect fires, electronic countermeasures (EMC), or smoke brought to bear on enemy personnel, weapons, or equipment to prevent effective fire on friendly forces *(Operational Terms,* 1985).

3. A factor liable to enhance some of the suppressee's capabilities *(Report,* 1975).

4. Suppressed behaviors are reactions that reduce individual or unit efficiency to fire, observe and move. Suppression is the fractional efficiency or effectiveness of a target in its functions (Winter et al., 1973, cited in *Report,* 1975)

5. One of the secondary effects of firepower *(Report,* 1975).

6. All enemies within the effective range of a weapon are forced to take some kind of passive or active countermeasure to protect themselves from the direct effect of the weapon's employment within its effective range. This indirect effect (sometimes called suppression or neutralization) may be as significant as the direct (Dupuy, 1985).

7. Suppression occurs when there is a 90-percent chance of 25 to 30 percent of the target being damaged. It is one of the damage levels along with the destruction (90-percent chance that at least 50 percent of the target or target area has suffered serious damage) and the harassment (a fire directed periodically against enemy troops to reduce morale and combat effectiveness) *(Soviet Tactics,* 1986).

8. Fire suppression is a process which causes temporary changes in the performance capabilities of the suppressee from those expected when functioning in an environment he knows to be passive; these changes are caused by signals from delivered fire, or the threat of delivered fire, and they result from behaviors that are intended to lessen risk to the suppressee *(Report,* 1975).

3.2.2. Psychological Definitions

There are also numerous related psychological definitions of the term suppression as well. To cite a few:

1. It is an adaptive mechanism for dealing with information processing. This master mechanism or group of mechanisms of the central nervous system is responsible for (a) scanning and screening incoming information, (b) processing new and old information to modulate the state and content of conscious awareness, (c) integrating or associating new information with previously stored information, and (d) controlling information output in the form of behavioral responses. Only a minute portion of the total available information from the external environment, from within the body, and from the brain's own stores can be held in awareness at any given time (Freeman et al., 1972)

2. A conscious attempt to withhold psychologically painful material (Freeman et al., 1972).

3. Conscious act of controlling and inhibiting an unacceptable impulse, emotion, or idea. Suppression is differentiated from repression in that the latter is an unconscious process (Freeman et al., 1972).

4. Because anxiety precipitates a fight-or-flight reaction, the human organism develops defenses to protect itself. And one of them is suppression (Freeman et al., 1972).

5. The individual tells himself that he will not remember some traumatic event or situation; subsequently he tries to believe and behave as though he were amnesic for that time (Coleman et al., 1976).

3.2.3. Dictionary Definitions

Observing such *variety* in the above noted definitions regarding this *one* term, one will be lead next to the dictionary definitions in a search for a consistent description.

Quoting Webster's Third New International Dictionary of the English Language Unabridged (1961), suppression is:

1a. The action of suppressing or the state of being suppressed. 1b. The instance of suppressing.... 3. The conscious intentional exclusion from consciousness of a thought or feeling—contrasted with repression....

The verb suppress is defined as follows:

1a. To put down or out of existence by or as if by authority, force, or pressure: subdue. 1b. To force into impotence or obscurity. 1c. To extinguish by prohibiting, dissolving, or dispersing.... 3a. To exclude from consciousness. 3b. To keep from giving vent to: hold back. 4. To press down....

Summarizing, there is a great deal of inconsistency among the presented definitions of suppression, the military ones in particular. It is evident that the term has been used in the military quite loosely and imprecisely.

Due to its complexity, the efforts to define "suppression" uniformly and in a single military definition will most likely remain elusive. Perhaps exchanging this term with some other nomenclature would be more appropriate. Or perhaps an additional modifier is needed to be used in conjunction with the term so the meaning will be clear.

3.3. DEFINITION OF INDIRECT EFFECTS OF WEAPONS

"Indirect effects of weapons" is the term used in this report to describe the non-physical damage effects of weapons. The working definition of the *indirect effects of weapons* for the purpose of this report is as follows:

> The measurable cessation in, deviation of, or alteration of an individual's behavior or performance resulting from the non-physical effect of combat mechanisms, which consequently lead to an alteration or a malfunction of any part of any subsystem or of the entire combat system.

The causative mechanisms for these effects are general combat stress, a near miss, or other related non-physical damage combat factors. These mechanisms lead to sensory/perceptual, cognitive, motivational, or emotional impairment of crew; this in turn leads to performance failure or degradation of combat hardware, any combat subsystem, or the entire combat system. The effects can be either short-term (lasting seconds, minutes, or hours, and reversible on the battlefield) or long-term (nonreparable on the battlefield, e.g., hospitalized psychiatric casualties and others). This definition also encompasses the ***positive*** effects of weapons in which the individual's performance might be actually enhanced or in which the personnel or hardware "survive" as a result of taking a cover or any other protective/defensive posture; however, this will not be addressed in this report.

3.4. TAXONOMY OF INDIRECT EFFECTS OF WEAPONS

Construction of a simple model for the indirect effects of a weapons will not suffice, hence the establishment of several different submodels is proposed. To describe a combat system, it is necessary to establish a taxonomy reflecting its multidimensionality. To build this methodological approach, the combat system is arbitrarily dissected into various combat subsystems.

The proposed combat system taxonomy is as follows:

- Individual/Personnel Subsystem
- Visual Acquisition/Surveillance Subsystem
- Firepower Subsystem
- Maneuver/Mobility Subsystem
- Communication Submodel
- Decision Making Submodel

This taxonomy is not meant to be all-inclusive, as there are other combat subsystems that exist on the battlefield, such as combat support systems, and others.

The proposed combat model for indirect effects is based on the above mentioned classification. The main concentration in this model is on individual, as opposed to unit, combat task performance.

The five proposed submodels are listed below.

- Individual/Personnel Submodel
- Visual Detection Submodel
- Immediate Physical Threat (Firing) Submodel
- Communication Submodel
- Decision Making Submodel

Some of the submodel's names are identical to the combat system they represent, such as Individual/Personnel, Communication, and Decision Making. The Visual Acquisition/Surveillance Subsystem is represented by the Visual Detection Submodel, and the Firepower Subsystem by the Immediate Physical Threat (Firing) Submodel. As the individual soldier's activity is the main point of concentration of this proposed model, the Maneuver/Mobility Subsystem normally representing unit activity as opposed to an individual's activity, is excluded from this model classification. The issue of the indirect effects of weapons in the maneuver/mobility combat subsystem will be also addressed later in the Discussion section.

4. THE MODEL AND ITS COMPONENTS

In this model, the proposed submodels represent the indirect effects of weapons and the resulting performance degradation of crew. The model contains two main components, one concentrating on the *generalized* indirect effects, and the other on *function-specific* combat performance degradation.

As mentioned above, the main concentration is on individual, as opposed to unit, combat task performance. Also, generally, the presented curves are hypothetical.

The Individual/Personnel Submodel assigned to the generalized indirect effects component of the model concentrates on the indirect effects of battlefield stress. The main assumption in this submodel is that battlefield stress leads to *generalized/non-specific* degradation of a combat system via psychological incapacitation of an individual soldier.

The other four submodels, the Visual Detection, Immediate Physical Threat (Firing), Communication, and Decision Making, are categorized as the function-specific component of the model. They are based on the principle that indirect effects can also be specific and cause degradation of *specific* functions of any combat subsystem. Examples of these are degradation of acquisition by visual obscuration caused by a munition burst, or degradation of communication due to a loud noise produced by projectile impact. Typically, these mechanisms are triggered by a near miss and other related non-physical "damage". They lead to sensory/perceptual, or cognitive disturbances and, consequently, to performance degradation of a soldier and his assigned specific combat function.

4.1. THE GENERALIZED INDIRECT EFFECTS COMPONENT OF THE MODEL

Besides the physical damage mechanisms existing in combat, battlefield stress in itself increases personnel vulnerability and causes damage by producing psychological incapacitation in crew. This, in turn, may result in performance failure of a combat element.

The *generalized* effects of combat stress extend throughout the battlefield operation with all its combat subsystem functions, such as, firing, target acquisition/surveillance, movement, communication, and others. This submodel is built on the assumption that the generalized stress effects may degrade any combat subsystem where a soldier's *specific* combat activity, and his performance in general, might be disorganized as a result of *non-specific* combat stress causes. And the main emphasis in this Individual/Personnel Submodel is on the generalized/non-specific battlefield stress incapacitating effects.

4.1.1. THE INDIVIDUAL/PERSONNEL SUBMODEL

4.1.1.1. Battlefield Stress: Traumatic Combat Reactions and Psychiatric Casualties

When conditions of overwhelming stress occur, as in terrifying accidents, imprisonment, physical mutilation, or military combat, temporary mental disorders may develop, even in previously stable personalities (Coleman et al., 1976). Abnormal reaction to the acute stress of combat is not abnormal. Usually the individual shows good recoverability once the stressful situation is over or after a few days rest, sedation, hot food, recreation, and relaxation.

Medical interest in stress began on the battlefield where the devastating effects of chronic stress were first observed. During the Civil War, palpitations were so common that they became known as "soldier's heart". World War I produced a new theory, shell shock. The term was coined by British pathologist, COL Frederick Mott, who regarded such reactions as organic conditions produced by minute hemorrhages of the brain attributed to the vibrations from heavy artillery. It was gradually realized, however, that only a small percentage of such cases represented physical injury from the concussion of exploding shells or bombs. Most of these men were suffering instead from the general combat situation with its physical fatigue, ever-present threat of death or mutilation, and severe psychological shocks (Coleman et al., 1976).

In World War I, an estimated 10 percent of the men in combat developed combat exhaustion; however, the actual incidence is not known as the records were kept mainly on men evacuated from the front lines who were considered the most seriously disturbed cases.

During the era of WWII, W. B. Cannon (1953) and H. Selye (1974), had proven that psychological strain itself can cause dramatic hormonal changes and, hence, physiologic/somatic symptoms. At the time, those traumatic reactions received numerous new descriptors, such as "operational fatigue", or "war neurosis". Finally they were named "combat fatigue" or "combat exhaustion" in the Korean War and the Vietnam conflict.

Another frequently used term is psychiatric casualty which refers to a soldier who becomes ineffective in the combat role for reasons other than wound, trauma, organic disease or ineptitude, as described by Rath (1980). Another definition of the psychiatric casualty by COL (Ret) Glass is as follows: failure in battle role (has) to be manifested by symptoms or behavior acceptable to the combat reference group as representing an inability rather than an unwillingness to function (Glass, 1977, in Rath, 1980). Psychiatric casualty is also frequently described as a neuropsychiatric disorder.

Of the slightly more than 10 million men accepted for military service during World War II, approximately 1,363,000 (14%) were given medical discharges, of which approximately 530,000 (39%) were for neuropsychiatric disorders (Bloch, 1969); see Figure 2.

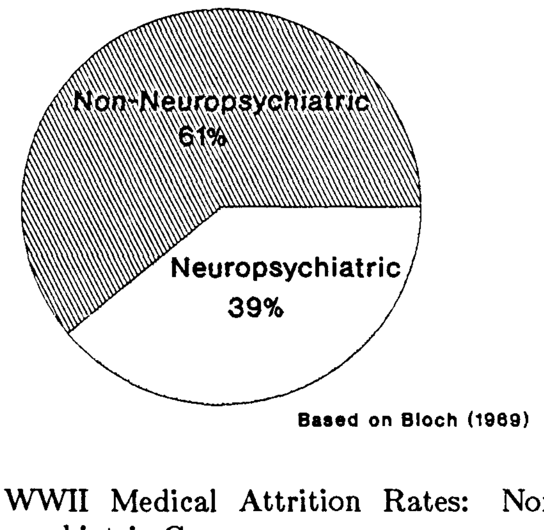


FIGURE 2. WWII Medical Attrition Rates: Non-Neuropsychiatric versus Neuropsychiatric Cases

The incidence of traumatic war reactions maintains a constant ratio to the number of men who were killed and wounded, indicating a definitive relationship between the severity of stress and the chance of emotional breakdown. The real threat to life was often associated with other severe stresses, such as lack of sleep, physical exhaustion, hunger, cold, loss of buddies, large numbers of casualties in one's outfit, wounds, injuries, and illness (Freedman et al., 1972).

Despite variations, however, there was surprising uniformity in the general clinical picture in both World War II and the Korean War. The first symptoms were a failure to maintain psychological integration, with increasing irritability, disturbances of sleep, and often, recurrent nightmares. In the recorded cases of combat exhaustion among soldiers in all three wars (WWII, Korea, Vietnam), the common core was usually overwhelming anxiety. Some soldiers who had stood up exceptionally well under intensive combat experiences developed what might be called "delayed combat reactions" upon their return home, often in response to relatively minor stresses in the home situation that they had previously been capable of handling (Coleman et al., 1976). At present, this is known as a post-traumatic stress disorder.

Length of continuous exposure to stress is crucial too. As number of combat days increase, number of psychiatric or neuropsychiatric casualties (NP) increase monotonically, according to Levin (1986):

$$\text{NP Casualties/1000 Men/Combat Day} = 10.8 - 9.6 \exp(-0.04\ D)$$

where,
D = Days in Combat

Based on the data table found in Levin (1986, p. 6), the following curve regarding NP/wounded-in-action (WIA) is drawn (Figure 3).

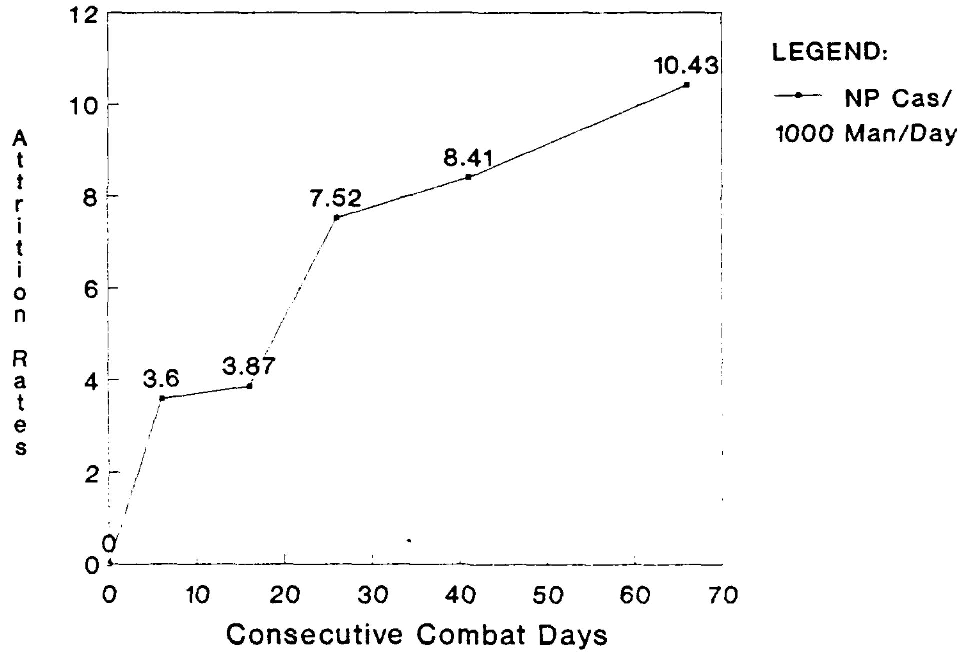


FIGURE 3. NP Casualties Rates as a Function of Combat Days: Ratio of NP Casualties to WIA versus Number of Consecutive Combat Days[1]

Attrition rates from *all* causes in combat, based on WWII European Theater of Operations (ETO) data, are:

> 50% by the 18th combat day,
> 75% by 34th, and
> 83-92% by day 50.

50% of soldiers who survived up to 80 days of combat would become neuropsychiatric casualties if remaining in combat beyond this time frame (Beebe, also Levin, 1986).

It is worth noting that some percentage of neuropsychiatric/battle fatigue casualties are restored to "normal" function on the battlefield, and therefore, are never withdrawn from the combat zone. Hence, typically they do not contribute to recorded attrition rates. Nevertheless, psychiatric reactions or battle fatigue rates contribute greatly to indirect effects.

1. This includes infantry as well as non-combat soldiers.

In the Korean War the incidence of combat exhaustion dropped from an initial high of over 6 percent to 3.7 percent; 27 percent of medical discharges were for psychiatric reasons (Bell, 1958, cited in Coleman et al., 1976). In the Vietnam War the figure dropped to less than 1.5 percent for combat exhaustion, with a negligible number of discharges for psychiatric disorders (Bourne, 1974; Allerton, 1970; cited in Coleman et al., 1976).

The marked decrease in combat exhaustion cases in the Vietnam War was apparently due to a number of factors, including (a) improved methods of selection and training, (b) confidence in military leadership, (c) the sporadic nature of the fighting, in which brief intensive encounters were followed by periods of relative calm and safety (as contrasted with weeks and months of prolonged combat that many soldiers went through in World War II and the Korean War) and (d) a policy of rotation after twelve months of service (thirteen months for Marines). Apparently it is easier for soldiers to tolerate combat stress for a known period of time, after which it becomes "somebody else's war" (Coleman et al., 1976).

The other cause of lowering of NP attrition rates was improved intervention methods and introduction of the proximity of treatment principal in which affected soldiers were "treated" in close physical proximity to their combat zone which prevented the occurrence of so called secondary-gain-from-illness symptom, a psychological protective/ defensive mechanism which leads to a lack of desire to recover in order to not be returned to the combat zone.

According to Coleman et al. (1976) and Freedman et al. (1972), sociocultural related factors that tend to raise the combat soldier's stress tolerance are clarity and acceptability of the war mission, identification with the combat unit, esprit de corps (the morale of the group as a whole), quality of leadership (confidence in military leaders), fair discipline, fair rewards and punishments, development of the "buddy system", pursuit of short-range military objectives (as opposed to pursuit of long-range ones), the expectation of relief from the stress after some definite time, adequate training, proper assignment, confidence in weapons or instruments, and others. The relatively simple technique of teaching soldiers that fear in the face of danger is normal and that fear can express itself by various bodily symptoms proved reassuring to many men.

One of the causes of traumatic combat reactions is the necessity of killing; most American servicemen, or anybody with a common set of the Western values, have strong moral convictions against killing or injuring others. Length of combat duty is another contributory factor: the longer a soldier is in combat, the more vulnerable and more anxious

he is likely to feel. Personal characteristics could also account for some lowering or increase of resistance to stress: the soldiers who function most effectively and are most apt to survive the rigors of combat usually come from a background that fostered sufferance, ability to function in a group, and ready adjustment to new situations (Bloch, 1969; Grinker, 1969; Lifton, 1972; Borus, 1974; cited in Coleman et al., 1976).

According to Vineberg (1965) based on WWII, ETO data, the number of combat casualties was lower but NP/WIA rates were consistently higher for armored divisions than for infantry. By contrast, airborne divisions suffered high numbers of casualties but had consistently lower NP/WIA rates. The Israeli wars data confirm this as well.

Higher intensity combat is associated with an earlier occurrence of neuropsychiatric casualties. In the modern Israeli wars of 1973 and 1982, NP/WIA ratio varied from 30 to 50%, with 100% reported in some units. Elite troops (airborne) suffered fewer casualties than regular combat troops. Among conventional fighting forces, the armored forces had the highest NP/WIA ratio, the artillery was intermediate, and the infantry had the lowest proportion of neuropsychiatric cases per WIA (Levin, 1986).

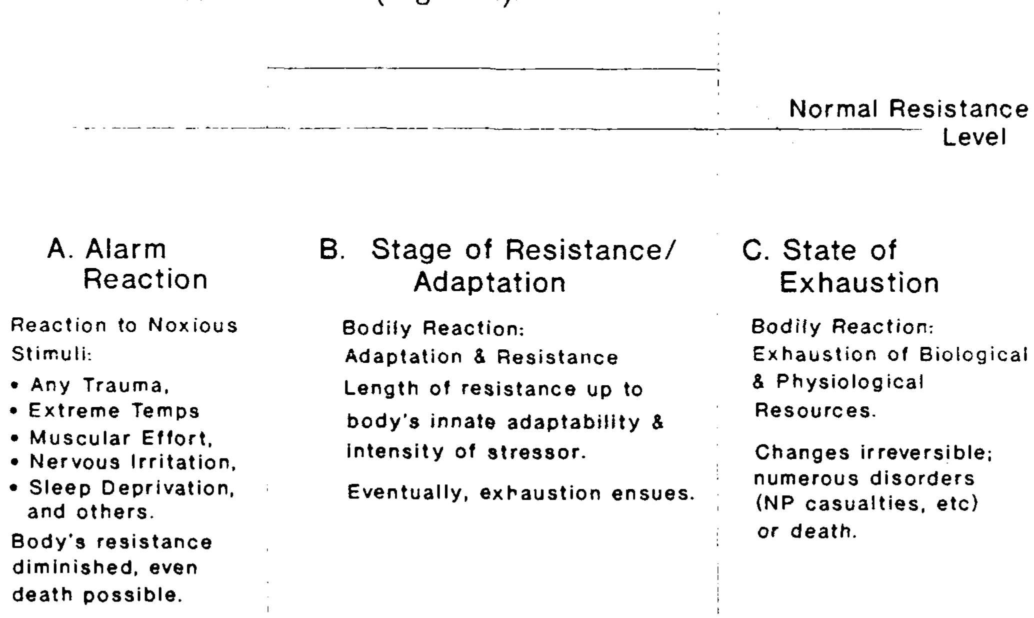
The conditions that were most often associated with the occurrence of neuropsychiatric casualties in the Israeli wars are as follows (Levin, 1986): near miss of an incoming round, sight of a buddy or an officer killed or wounded nearby, and also, a feeling of isolation and a sense of helplessness.

The current high technology, the increased firepower, accuracy and lethality of weapons, greater number of "pulses" per day, and others, change the concept of traditionally defined combat intensity. The high intensity Israeli wars of 1973 and 1982 might be a model for future combat (Levin, 1986).

4.1.1.2. What is Stress?

Humans have the capacity to withstand a massive dose of acute stress. However, when a typical stress reaction of fight-or-flight becomes chronic, as in battle, long-term chemical changes occur leading to numerous bodily dysfunctions (i.e., increased blood pressure, depression of the immune system, and others). These changes degrade human performance, hence there is incapacitation as a result of the weapon's indirect mechanisms.

After all, what *is* stress? It is a characteristic chain of biological reactions to various noxious/harmful agents which mobilize physiologic resources. It can be described as the General Adaptation Syndrome (G.A.S.) or biological stress syndrome (Selye, 1974). It has three distinctive phases: alarm reaction, stage of resistance/adaptation, and state of exhaustion (Figure 4).



Based on Selye (1974)

FIGURE 4. Stress: Chain of Biological Reactions to Noxious Stimuli

The chart represents changes in physiological status while under stress over time. The straight horizontal line expresses normal resistance level with no stress being present and the line overimposed over the straight line represents changes of the resistance levels under stress over a period of time. The alarm reaction can be provoked by many stressors, such as, exposure to sight of a near miss burst, loud noise due to explosion, extreme muscular effort, sleep deprivation, and others. At this stage, the body's resistance lowers; and this can lead to performance degradation, or in extreme circumstances to death. In the next stage, the soldier adapts to this stress and his physiological defense mechanisms become activated. This not only restores his resistance to a normal level but also beyond it; the performance level will likely increase at this stage. At this stage of Resistance/Adaptation, the body's innate adaptability resources are mobilized at the highest level. This elevated but plateau level of increased resistance persists for a certain period of time, and if the stressor continues, the Stage of Exhaustion will take place, as all physiological mobilization resources eventually become exhausted.

It is likely that a soldier is most vulnerable to indirect effects and, thus, performance degradation, during:

Stage A, the initial stages of stress stimulus; and

Stage C, following the adaptation stage as long-continued exposure to the same stressor leads to exhaustion of adaptation energy. Death or severe dysfunctions, e.g., long-term psychiatric or neuropsychiatric (NP) casualties, may occur.

4.1.1.3. Stress and its Influence on Performance

To model human performance degradation in combat, it is necessary to draw a relation between performance and psychological arousal factors. Arousal is a typical reaction to any stressor, either external (environmental) or internal ("mental").

Performance level is in part a function of motivation level; the higher motivation to perform (for various reasons and under various conditions, including battle) the higher the arousal, and therefore, the stress level. On the other hand, not enough motivation-to-perform will produce a poor performance. In the behavioral sciences, this is known as the Yerkes-Dodson law (Broadhurst, 1957). Refer to Figure 5 for illustration.

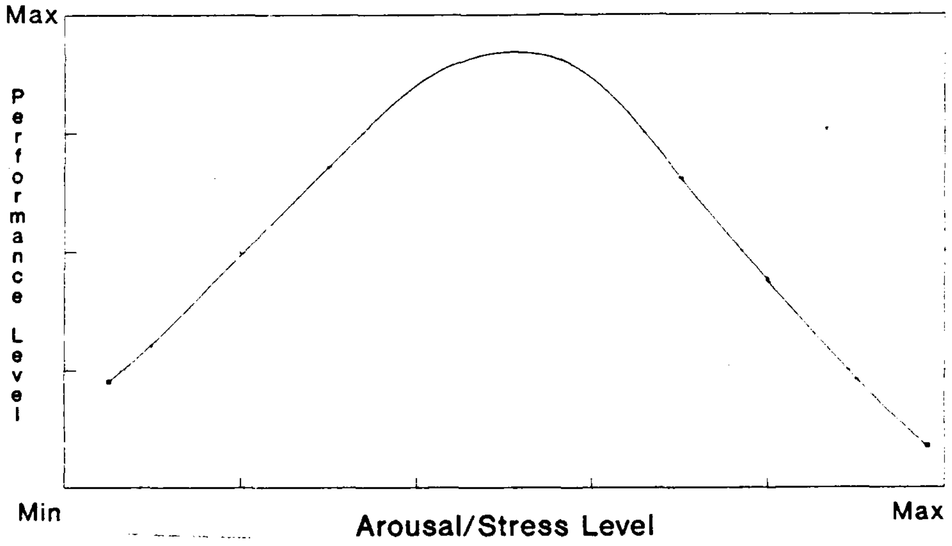


FIGURE 5. Relationship between Stress Level and Performance

A certain level of stress or arousal is needed to increase performance; too low levels of stress will degrade performance and too high levels of arousal/motivation produce deterioration in performance as well. In the middle range of the spectrum, there is an optimal arousal level for the best performance on a given task.

The levels of arousal/stress for optimal performance of a particular task, however, relate to the task difficulty. Beyond (above or below) certain optimal stress levels performance will decline. Generally, the lower the task difficulty level, the higher the optimal stress level; also, the higher the task difficulty level the lower the required optimal stress level (Figure 6).

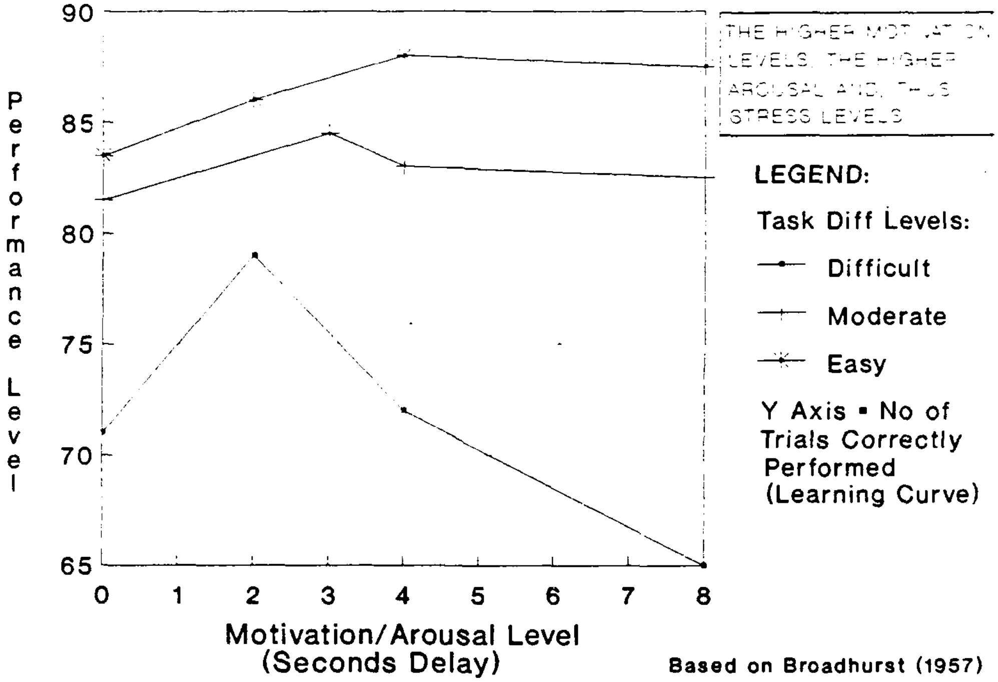


FIGURE 6. Performance Level as a Function of Arousal/Stress Level

In combat, performance of complex and difficult tasks will likely be affected by stress more readily than easy assignments. The easy task will also require a higher stress level than the difficult ones for optimal performance. The presented performance-versus-arousal/stress curves can be used in establishing modeling algorithms.

The issue of human physical limitations is highly relevant in the context of battle as well, especially in sustained/continuous operations. Fatigue is a reaction to prolonged or intense stress and it causes performance degradation. Other factors, such as environmental variables (e.g., temperature, terrain, weather), circadian cycles, the

individual's physical and psychological status (e.g., amount of sleep before the battle, previous work rate, food/water intake, severity and duration of a stressor), state of training, leadership, and other elements have to be considered.

IMPLEMENTATION STRATEGY

Including the variable of "stress" in a combat model is a necessity considering the nature of combat as discussed in this section. However, development of specific modeling routines will not be a simple task. The complexity of human responses to combat stress and interpersonal and intrapersonal differences need to be taken into account.

One of the crucial relationships is expressed by the "stress curve", General Adaptation Syndrome (G.A.S.) curve (Figure 4) which represents the stress-response chain of events in time. The stages of stress reactions and their behavioral, and even physiologic, manifestations can be clearly defined for the Alarm Reaction, Resistance/Adaptation, and Exhaustion phases. Specific tasks can be identified and their degradation or improved performance can be analyzed for each phase. The other variable, time, is a complicating factor as it has to be based on specific real-life combat or experimental or equivalent high-stress data. Such data are not readily available.

The other modeling aspect requires expressing differences in task performance degradation depending on task difficulty and its relation to stress levels. The tasks could have the "difficulty" levels arbitrarily assigned; this would allow one to group them into, for instance, three categories: easy, moderate, and difficult. For this, certain hypothetical "task stress" numerical values could be inferred from the relationships experimentally defined by Broadhurst (1957) and illustrated in Figure 6 ("Performance Level as a Function of Stress/Arousal Level"). Optimal performance levels could be assigned to each task. And following Broadhurst's, or related curves, certain predictions regarding performance degradation could be made.

The neuropsychiatric casualty is a generalized manifestation of combat stress and it is an example of an indirect weapon's effect. It could be used as a predictable combat incapacitation variable. However, the available neuropsychiatric casualty data are mainly applicable to unit level performance, not to individual analyses. In addition, the main source of psychiatric attrition data is WWII, the applicability of which to "modern" warfare might be questioned. Perhaps data obtained in the "modern" Israeli wars are more appropriate, assuming that the Israeli wars are models for future wars as argued by Levin (1986). The quantitative expressions of WIA and psychiatric ratios, as well as psychiatric casualties as a function of consecutive days in combat, are

available. Levin's *Mathematical Models for Prediction of Neuropsychiatric and Other Non-Battle Casualties in High Intensity Combat* (1986) is a good source for indirect attrition effects. It contains equations and other quantitative expressions of combat length and neuropsychiatric casualties to wounded-in-action ratios, and other types of indirect weapon's effects or losses. WWII data is used for low-intensity combat predictions and Israeli conflicts for inference of non-physical casualties in a high intensity war.

4.2. THE FUNCTION-SPECIFIC INDIRECT EFFECTS COMPONENT OF THE MODEL

The Individual/Personnel Submodel addressed the psychological combat casualty and indirect weapon effects as a *generalized* response to combat stress. The following four submodels are designed to represent *function-specific* weapons indirect effects caused by the other-than generalized combat stress. They model the way a near miss and other related factors degrade the performance of each subsystem.

A direct hit produces indisputable damage. It causes non-recoverable or reparable physical damage to any combat subsystem. The other damage mechanism to consider is non-physical damage. The near miss zone is a *non-physical* damage area where other-than-physical damage to personnel can occur. As non-physical indirect damage effects of weapons is the topic of this report, a near miss and other related damage factor are the main mechanisms considered in the function-specific submodels.

4.2.1. The Visual Detection Submodel

The near miss area is a non-physical damage zone where neutralization of an observer can occur. A near miss burst can alter the physical environment by producing smoke, dust, debris, fire, and other materials. There are other sources of obscurants as well. During such times, the ability to observe enemy forces is restricted and the observer is incapable or only partially capable of observing the enemy targets.

The probability of degraded visual ability is the chance of *no* acquisition/surveillance in the *first* time interval immediately following the onset of obscuration. The direct hit nearly always degrades visual performance. The probability of degradation in a near miss area relates to the distance of a subject from the impact point, as shown in Figure 7. The probability of degraded visual detection increases as miss distance decreases. The area beyond the near miss region is the no-effect area.

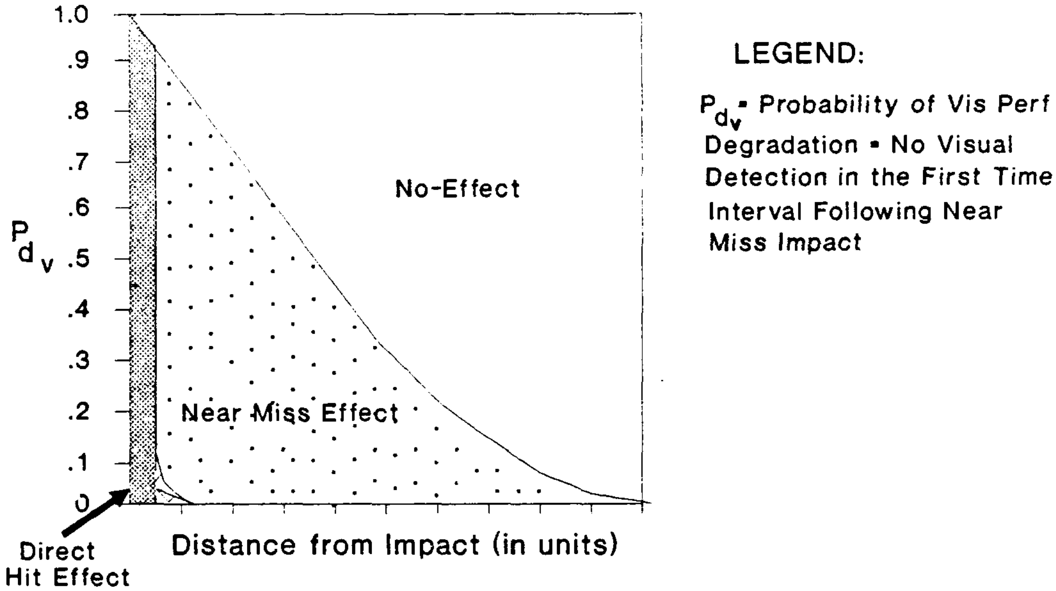


FIGURE 7. The Visual Detection Submodel: Impact of Near Miss on Visual Neutralization

When the observer's ability is compromised by an obscurant in this first time interval, the ability to acquire a target in the immediately succeeding time interval is diminished, as well. This is because the observer's ability to make an optimal decision in this interval is adversely affected by lack of information about the enemy position during the previous time interval. Thus, degradation effects extend through at least two time intervals, with the second period being affected to a lesser degree; see Figure 8.

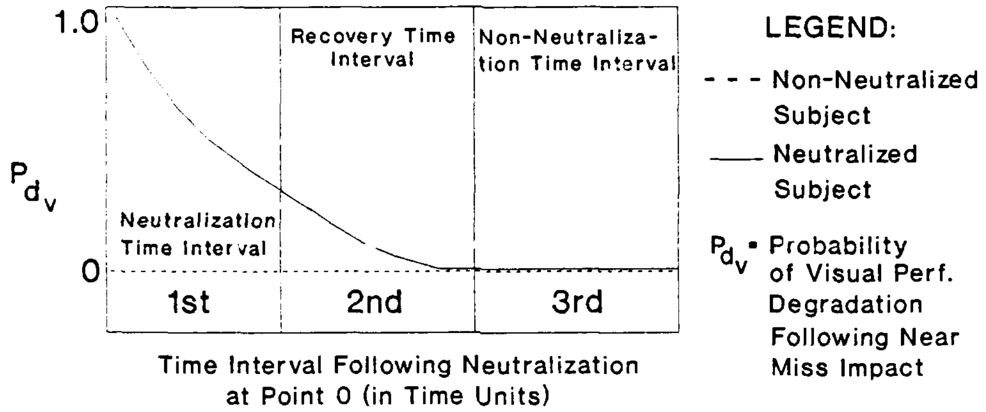


FIGURE 8. Human Performance Degradation in Visual Detection upon Near Miss on a Line of Sight

An affected observer is either totally incapable or only partially capable of detecting enemy targets and his enemy target acquisition/surveillance activities are compromised in this first time interval following stimulus application. The longer the neutralization period, the more degrading effect it can have. Figure 9 illustrates these assumptions.

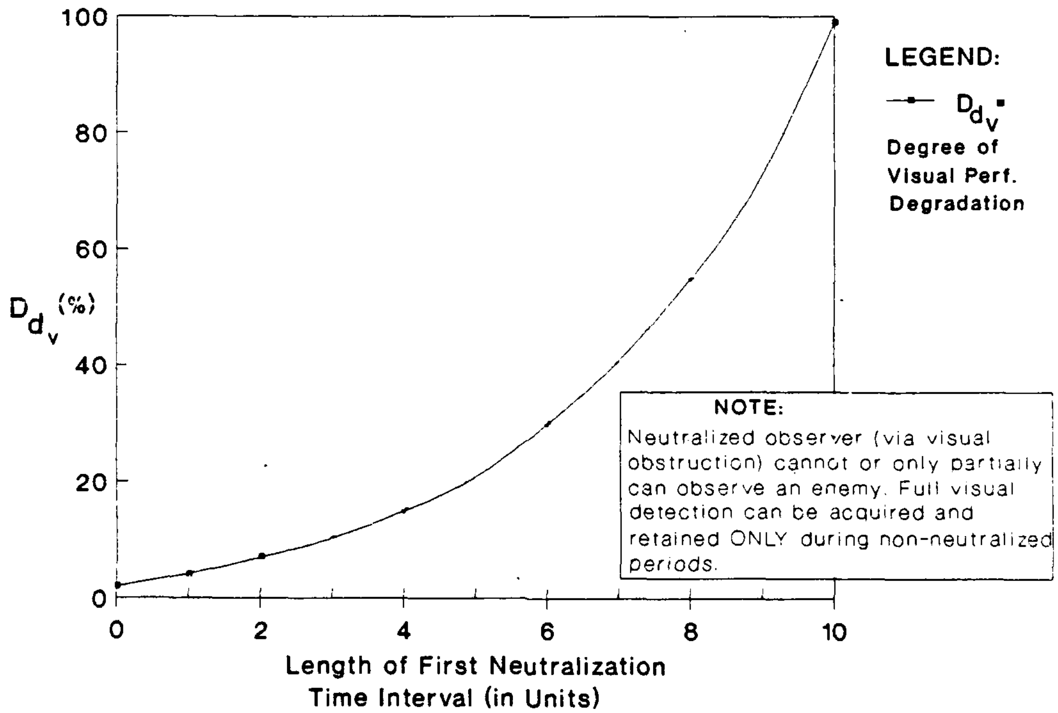


FIGURE 9. Length of Exposure to Near Miss Stimulus and Degree of Visual Detection Performance Degradation

The amount of visual degradation depends on the location of the near miss. Obscuration in front of the subject or in front of the target, and hence visual obstruction directly in the line of sight, produces a higher chance of performance degradation in the observer than near misses on the side of or behind the observer.

IMPLEMENTATION STRATEGY

Some of the variables in the model, such as time of obscuration or location of an obscurant in relation to an observer (i.e., side, front), can be modeled for specific visually obstructive media. The analysis could include various military obscurants; for example, different types of smoke, such as fog oil, dust, phosphorous, and others. Visual obscurant indices could be established for each type of obscurant under various atmospheric/meteorological conditions.

Various warhead types and their "obscurant producing" qualities could also be analyzed. Also, the number of rounds for a particular weapon/projectile hitting an area of a given terrain type produces a predictable amount of debris and related material. Additionally, the time values for these indirect effects could be measured indirectly by analyzing the time needed for a particular obscurant to clear.

Establishment of the degree of visual performance degradation as a function of exposure time interval (see Figure 8) is complex. Hardware that is physically damaged by a direct hit will require a certain "repair time" (if reparable at all), which can be measured. However, the down time for a system as a result of human incapacitation related to non-physical damage mechanisms, are not easily predictable. There is a large number of uncontrollable variables involved. Therefore, the modeling of time degradation requires the availability of real-life or experimental data. The sources of such data are research and analyses conducted at the U.S. Army Atmospheric Sciences Laboratory and the U.S. Army Project Manager—Smoke/Obscurants.

4.2.2. The Immediate Physical Threat (Firing) Submodel

Firing rate and accuracy can be affected *individually* or *in combination* with other combat subsystem activities such as search for and observation of targets (as in the previously discussed submodel), maneuver/mobility, command and control, and others. This model will abstract from the complexity of combined effects of combat subsystems and will concentrate on indirect effects on *individual conventional* fire. The main concentration in this submodel is on the immediate physical threat due to hostile fire, and performance degradation as a result of a crew's behaviors dictated by a sense of personal safety and other related factors.

In firing, the closer to the center of hit the more pronounced the kill effects. While considering a non-physical damage mechanism, hypothetically, the indirect effect is a function of miss distance. The closer to the near miss, the greater the indirect effect. Beginning at the direct effect area of the circle, the near miss area begins where the direct effect area ends; and beyond the near miss area lies the no-effect area where the effect is either negligible or does not exist (see Figure 10).

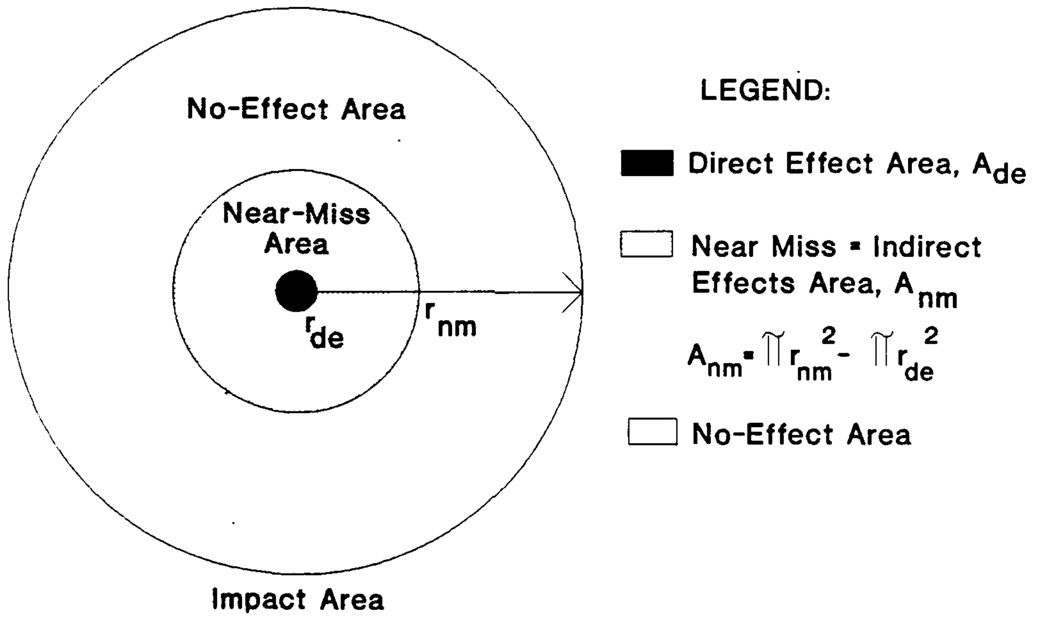


FIGURE 10. Firepower Submodel: Location of Impact Points and Non-Physical Damage Effects

The probability of degrading the crew's performance with a near miss, P_d, is the chance of no expected combat activity, or inappropriate activity. P_d is a function of r and time.

Assuming that the near miss area is in the shape of a circle, the closer to the direct effect area the higher chance of performance degradation in the first time interval following stimulus application. P_d reaches the value 1.0 at and after crossing point r_{de}. Degradation is complete at r_{de}, and drops to zero at r_{ne}.

$$P_{d_{nm}} = P(r_{de} < r_{nm} < r_{ne})$$

$$P_{d_{de}} = 1; \quad P_{d_{ne}} = 0$$

The hypothetical curve is shown in Figure 11.

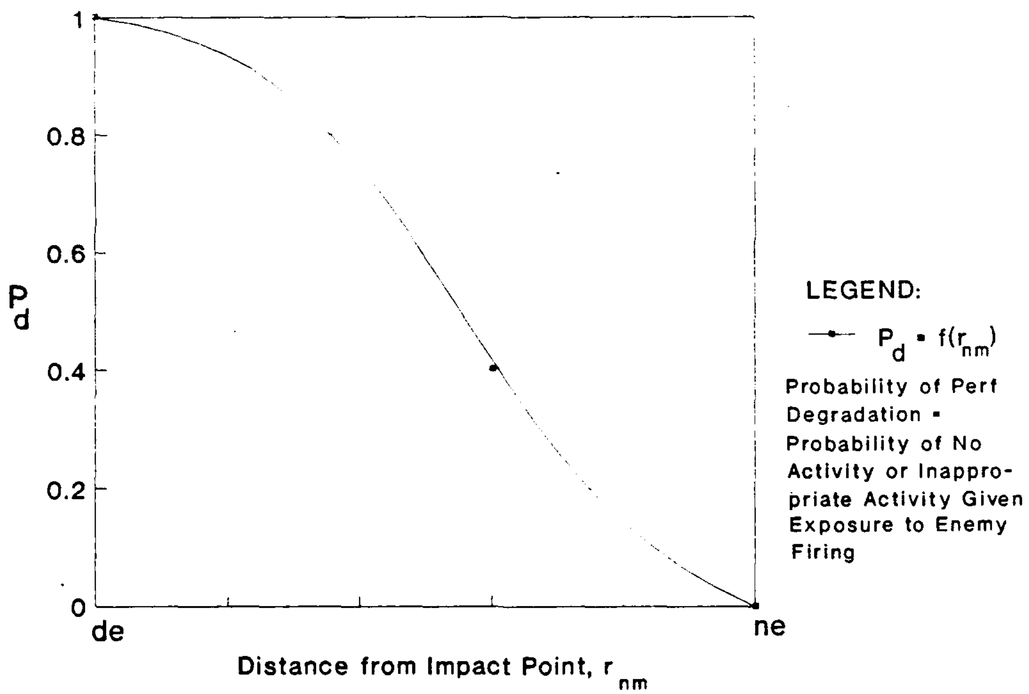


FIGURE 11. Performance Degradation as a Function of Distance of Near Miss Impact from a Subject.

Caliber and number of incoming near miss rounds impacting in the near miss area are other variables that can influence crew's performance and cause its degradation. This indirect effect might be an increase in or inappropriate reaction time to aim/fire/load, decreased accuracy in firing, lack of fire, and other inappropriate responses. If a certain near miss location is the same for all, the higher the caliber of rounds the higher the chance of indirect effects. Also, the higher number of rounds per specified time interval the higher the chance of indirect effects. Figure 12 and Figure 13 show these hypothetical relationships.

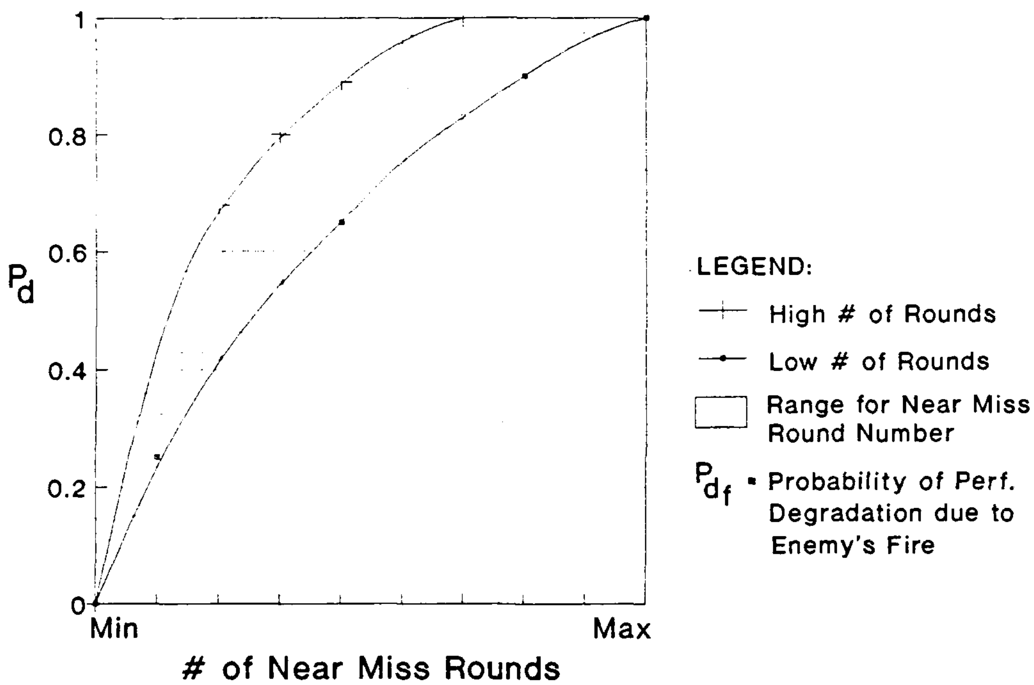


FIGURE 12. Fire Activity: Weapons' Indirect Incapacitation Effect as a Function of Number of Near Miss Rounds

Combining these two firing factors' effects, caliber and number of rounds, will most likely produce at minimum an additive, and perhaps a synergistic response.

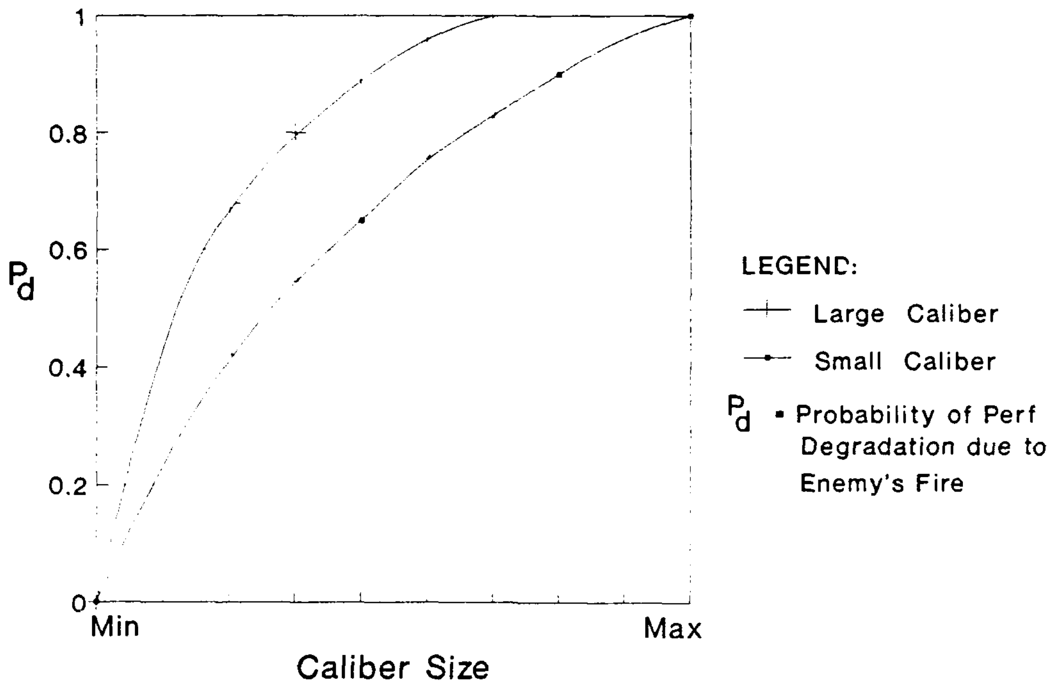


FIGURE 13. Weapon's Indirect Incapacitation Effect as a Function of Near Miss Round's Caliber Size

IMPLEMENTATION STRATEGY

The probability of degradation of any crew's combat activity upon exposure to enemy firing with no physical damage to crew is the chance of no expected combat activity or inappropriate activity given a near miss. The indirect firing effects area could be defined by using the formula in Figure 10; the size of this weapons' indirect effects area, which constitutes the near miss area, is dependent on the radial distance of a subject from a hit:

$$A_{nm} = \pi r_{nm}^2 - \pi r_{de}^2$$

where
A_{nm} = Near Miss Area
r_{nm} = Radius of Near Miss Area
r_{de} = Radius of Direct Effect Area

Different r_{nm} values could be assigned different performance degradation indices, I_d. The closer to the direct effect area the higher the chance of reducing performance in the first time interval following a near miss, hence the higher index value. The further away from the r_{de} point in a direction approaching the no-effect area, the lower the chance of performance degradation/indirect effect; thus, the I_d value

would decrease. I_d for the no-effect area would equal 0. Finding r_{de} should be easy because it is the area beyond which the direct hit carries no physical damage effect. However, the outer limits of the near miss area in the direction of the no-effect area, will probably be very difficult to establish.

The weapons' indirect effects and crew's performance degradation upon enemy firing activity can also be quantitatively related to the munition types, their calibers, and number of rounds for the near miss area and other related factors.

4.2.3. The Communication Submodel

Communication is a critical combat activity. It occurs and its correctness is vital at *all* echelon levels; the communication system, however, is the nucleus of command and control.

A direct hit on a communication center *will* undoubtedly degrade communication at the moment of hit. A near miss can also affect the activity despite a lack of physical damage to a communication system through such means as noise, sensory/perceptual and/or cognitive disturbance of an operator, and other related mechanisms. As in the other previously presented function-specific submodels, the concentration in this submodel is on near miss effects and other related nonphysical damage mechanisms.

The communication process involves *expressive* and *receptive* communication mechanisms. Expressive communication is the process of *sending* a signal to a receiver. Receptive communication involves the ability to *receive* a transmitted signal by any means (e.g., voice, radio, hand signal, smoke). The impairment of receptive capability occurs during electronic jamming, or when noise produces an inability or decreased ability to hear a message, or when a visual obscurant (e.g., flying debris, smoke) prevents seeing arm and hand signals or other visual communication means (i.e., colored smoke, chemical light). Expressive communication fails when there is an inability or decreased ability to transmit a message to a receiver. This applies to direct verbal person-to-person, electronic, visual and other communication methods. Impairment to both receptive and expressive mechanisms increases communication time or an inability to communicate. A hypothetical curve for voice communication degradation related to noise is presented in Figure 14.

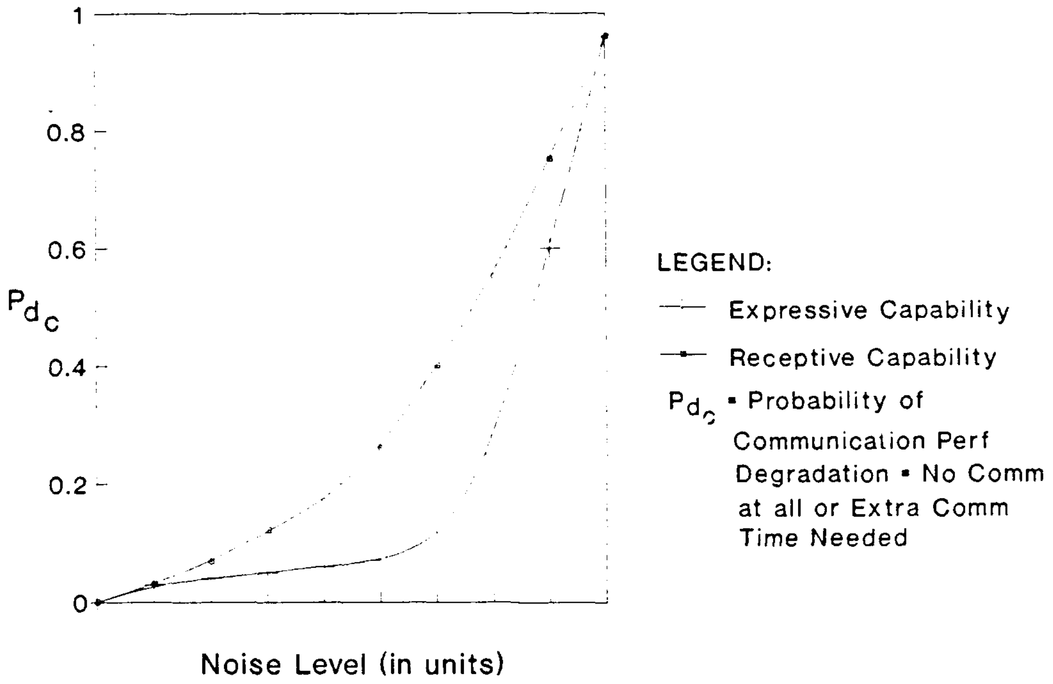


FIGURE 14. Indirect Effects of Weapons in Combat Communication: Communication Time as a Function of Noise Level

IMPLEMENTATION STRATEGY

The initial effort could involve categorizing communication devices according to the type of communication signals they produce: direct voice, electronic, hand and other "visual" signals, such as, colored smoke, chemical light, and others. Each of these signals could have an indirect incapacitating effect or susceptibility index assigned which could be directly related to receptive and also expressive performance degradation as a result of a near miss. Susceptibility indices should be weighed against communication reception disturbance variables (noise, visual obstruction, and others) and also their possible impact on tactical or strategic planning/damage their impairment would cause. The task of defining and also assigning values to those susceptibility indices however, will most likely be very complex.

Furthermore, environmental and weather conditions play an important role in facilitating or degrading communication. Therefore, to model communication, various environmental/weather conditions could have different degradation correction factors assigned.

4.2.4. The Decision Making Submodel

Decision making occurs at all echelons; however, the timeliness and correctness of a decision is particularly critical at the command and control levels. This submodel concentrates on decision making under stress and its time dependence on the "level of expertise" of a decision maker.

The consistent research findings show that under time pressure, the decision maker adopts a simpler mode of processing information focusing attention on the one or two most salient clues. Negative information also becomes more important under time pressure, and if the situation involves a risk, time pressure leads to more cautious, risk-avoiding behavior, with greater importance given to avoiding losses (Bales, 1988). An illustration of decision making in a stressful situation could be the USS Vincennes engagement in the Persian Gulf in 1988. Apparently, an error in human information processing and decision making processes caused by stress of intense battle engagement was one of the contributory factors in the incident. This information was provided during one of the congressional hearings following a study of the incident by psychologists (Bales, 1988). Generally, however, there has been far too little research on decision making under stress.

The other critical element to be considered in modeling the decision making process is the "level of expertise" of a decision maker. Expertise level influences the quality or correctness of a decision as well as the time required for decision making. Furthermore, the higher the expertise level, the lesser the chance of degradation of decision making activity under stress.

The level of expertise is a function of education, training, and practice effect (that is, the length of experience in a particular area related to the decision making) and also other factors. The question is, how do experts who achieve a high level of performance differ from those who are merely competent or just a novice? Does their masterful performance relate to their thinking or memory or some other skills?

Based on research findings of cognitive psychologists, the factor that separates experts from those who are merely competent or just novice is their superior knowledge of the specific area and not necessarily their thinking or memory abilities or some other cognitive skills. However, the expertise in one domain is no guarantee of expertise in others, as noted by Glaser (cited in Trotter, 1986); expertise seems to be very specific. Nevertheless, the mental processes of the expert who is totally involved in a skillful performance are the same regardless of the expert's field of expertise.

The stages of knowledge acquisition can be analyzed to determine differences in decision making patterns in performers at different stages of acquiring knowledge. As humans acquire a skill through instruction and experience, they do not appear to leap suddenly from rule-guided "knowing that" to experience-based know-how. A study of the skill-acquisition process shows that a person usually passes through at least five stages of qualitatively different perceptions of a task and/or modes of decision making as the skill improves. The stages of skill acquisition are as follows (Dreyfus et al., 1988):

- Novice;
- Advanced Beginner;
- Competence;
- Proficiency; and finally
- Expertise.

According to Dreyfus, the novice learns to recognize various objective facts and features relevant to the skill as well as rules for determining actions based on these facts and features. These basic rules ignore full complexity of the overall situation/context; they are context-free. Novices are usually so caught up in following the rules that they have no coherent sense of the overall task; they follow rules regardless of what else is happening. They do not usually know that there are certain situations in which these rules could be violated.

As he accumulates experience with real situations, the novice progresses into the the advanced beginner stage; his performance improves. He starts to consider more than context-free facts and learn that some actions are acceptable despite the lack of well-defined rules; he applies more sophisticated rules to deal with situational elements.

The next stage is competence. As Dreyfus explains, in this stage and with more experience, eventually the number of recognizable context-free and situational elements present in a real-world circumstance becomes overwhelming. Choosing a plan is no simple matter for the competent individual. There is no objective procedure like the novice's context-free feature recognition. Now, he must choose an organizing plan unlike an advanced beginner who can get along without recognizing and using a particular situational element. At the stage of competence, the person appraises the situation, sets a goal and then chooses a plan, which may or may not involve following the rules. He no longer merely follows rules and may at times even choose to break the rules. He learns how to take a calculated risk. Whether the plan succeeds or fails, the situation and its outcome leaves a vivid memory, an important resource for future expertise.

In the stage of proficiency, there is rapid and fluid action. As a result of experiencing similar situations in the past, memory triggers plans similar to those designed and used in the past. There is intuitive understanding, followed by detached decision making and thinking analytically about what to do. In the other earlier stages of expertise development, rules are carefully applied, plans are chosen deliberately and rationally, and decisions are made after considering various alternatives.

The two highest levels of skill, proficiency and expertise, are characterized by rapid and fluid behavior that bears no apparent similarity to the slow, detached reasoning of the problem-solving process. In the stage of expertise, there is no application of rules or conscious decision making. An expert generally knows what to do based on mature and practiced understanding. Experts do what comes naturally and it always brings a desired outcome. Their experience-based deep understanding of the situation leads to fluid performance and very rapid action. In skill acquisition, the novice and advanced beginner exercise no judgement. The competent performer judges by conscious deliberation, and those who are proficient or expert make judgements based on their prior concrete experiences in a way that defies explanation.

A novice, possessing talent and having the opportunity to acquire sufficient experience through practice, ultimately, will gradually become an expert. However, not all people reach an expert level in their skills; some areas of skill have the characteristic that only a small fraction of beginners can ever master.

With expertise comes fluid performance. Pilot proficiency, for example, is dependent on number of flight hours. And based on research by Fuchs and Cedel (1989), there is a clear threshold of 1400 flight hours that separates the most effective pilots from the remaining group, non-experts. Expert military commanders, in the time of attack "see" a situation based on whatever data are available and respond using common sense and experience, using their "intuition".

In crises, competence is not good enough. Someone at a particular stage of skill acquisition could imitate the thought processes characteristic of a higher stage but will perform badly when lacking practice and concrete experience, especially, under stress. In general, newly acquired/learned tasks tend to be affected by pressure/stress more readily than routine tasks. The expert in a specific area is very familiar with his tasks. However, to a novice or advanced beginner, who is just in the process of knowledge acquisition, these tasks are new or relatively new. Hence, under stress, the decision making time in experts will most likely be affected minimally, if at all, as compared to "a

lower level" decision maker. Figure 15 represents hypothetically these relationships for a task of average difficulty level.

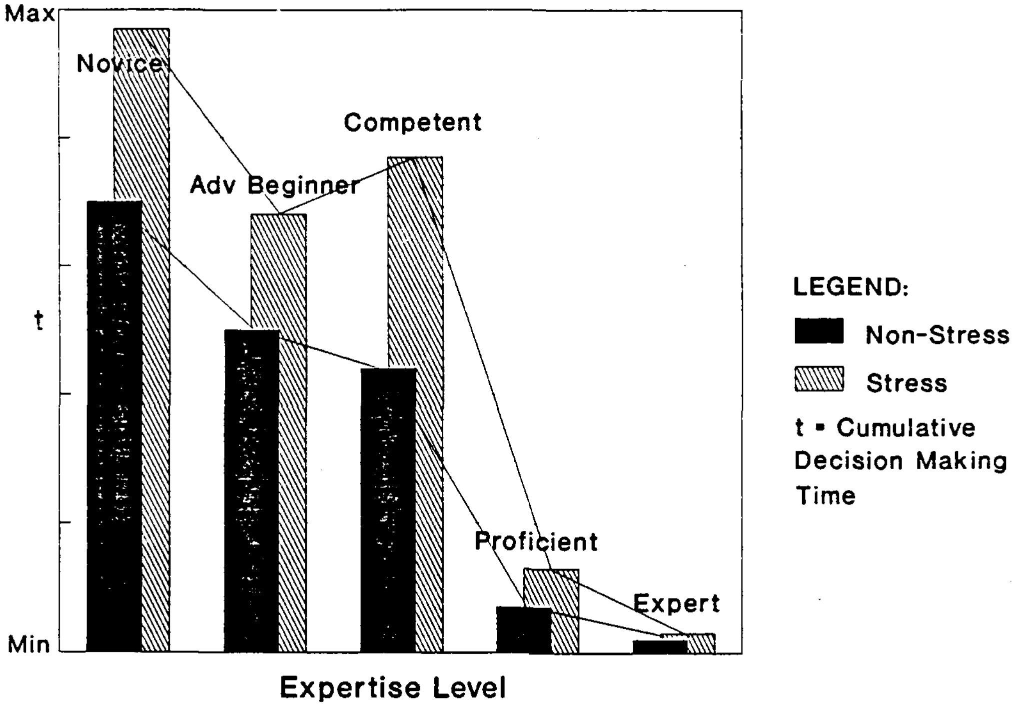


FIGURE 15. Indirect Effects of Weapons on Decision Making Time: Non-Stress and Stress Decision Making Time as a Function of Expertise Level

The experts' decision making is automatic, as they have developed the ability to perceive large meaningful patterns and do so with such speed that it appears almost intuitive. Since the decision making process in expert and proficient performers is rapid and fluid, their decision making time is shorter than in less advanced performers. The competence stage may require even somewhat longer times for decision making than in novices and advanced beginners, as they have an "overwhelming" amount of information "all of sudden" available to them; hence their analysis is more involved and time consuming. A benefit of the longer time needed may be a greater chance of a no-error decision as compared with more "time-expeditious" but error prone novices and advanced beginners.

Also the correctness of a decision is essential in combat. A related factor to error-free decision making is the state of certainty-uncertainty about the subject matter. That state can be expressed as a continuum extending from 0% - 100% uncertainty. The more uncertainty, the higher the chance of incorrect decision. And the uncertainty state is a function of expertise level. The chance of a correct decision increases as one progresses from novice to expert level (see Figure 16).

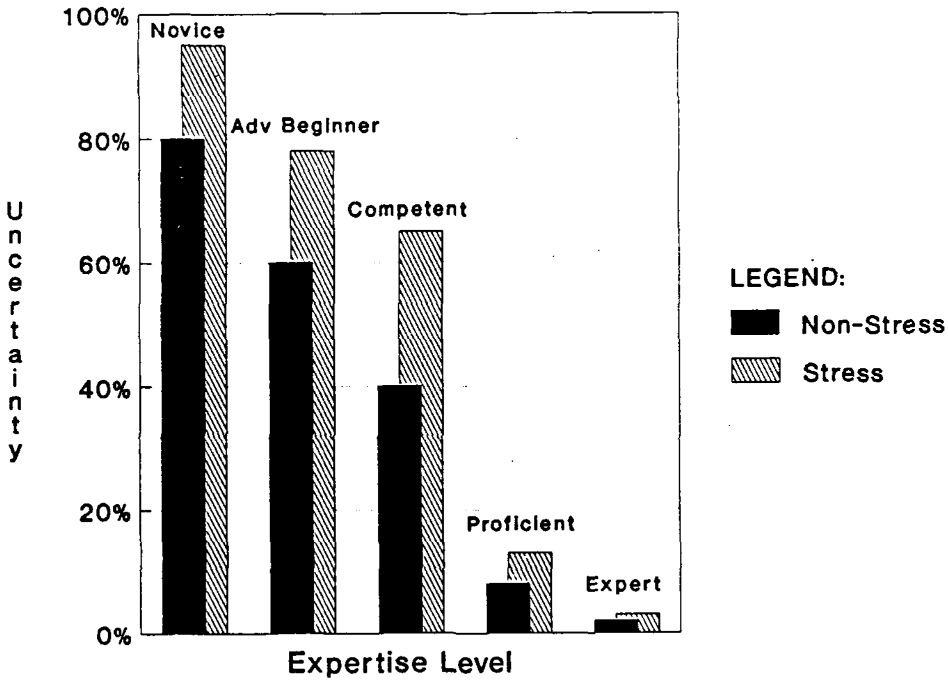


FIGURE 16. Decision Certainty-Uncertainty and its Relationship to Expertise Level

The chance of a correct decision is a function of expertise level. The hypothetical curve in Figure 17, illustrates this relationship.

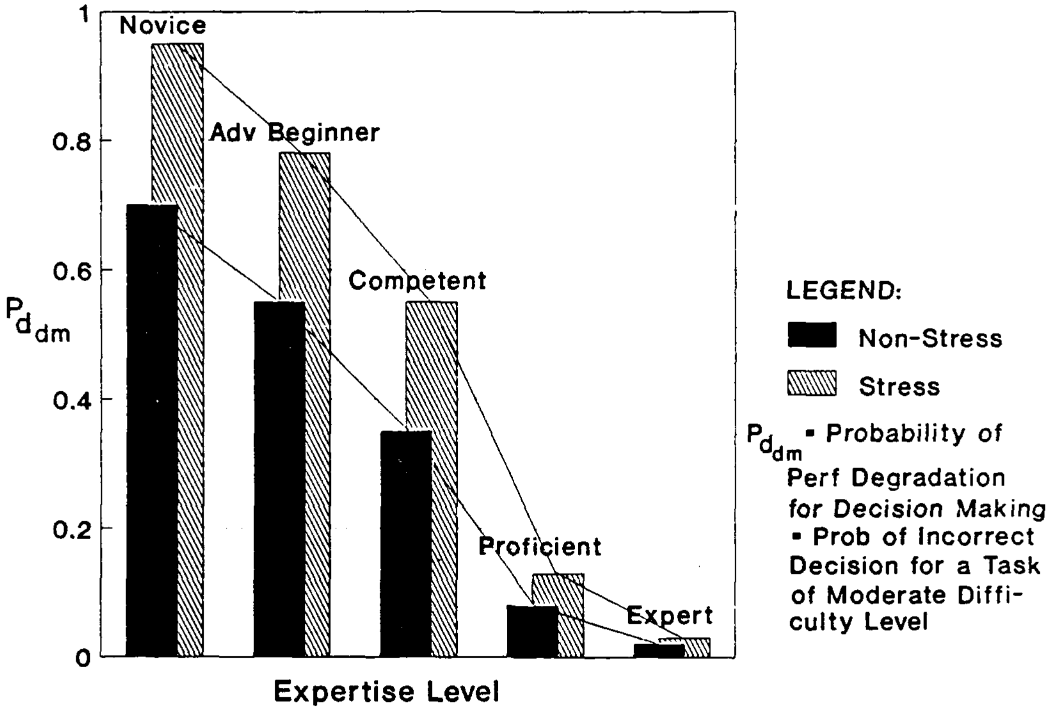


FIGURE 17. Decision Correctness as a Function of Expertise Level under Non-Stress and Stress Conditions

IMPLEMENTATION STRATEGY

Understanding the dynamics of decision making and its correctness is very important in modeling for a variety of reasons. Decision-making occurs at all echelons; however, the timeliness and correctness of a decision is particularly critical at the command and control level. The ideal expectation is that command and control functions are performed by experts. However, there are circumstances where sufficient knowledge, practice, or information are not available to leaders. Also in other situations, the assigned leaders might lack appropriate "expertise".

To simulate the decision making process in combat, a model of decision making under stress should be used. The initial modeling task would involve categorizing decision makers (leaders in particular) according to their level of expertise. Once a decision maker is assigned to a certain class, it is possible to predict his decision making time.

There is a large amount of experimental data available, especially in behavioral sciences, to support the analytical process in finding conclusions regarding decision making time. One difficulty may be the non-availability of "high stress" data. Also, civilian high stress data might not be applicable to military decision making in combat.

Another problem might lie in translating decision making for "civilian" tasks and drawing parallels to the military. Military task analyses including time tables for specific military occupational specialties (MOS) could be used.

The task difficulty level for a decision maker relates to his expertise level. Theoretically, experts find the majority of tasks not difficult because of the wealth of experience they possess. The beginners, however, find many tasks to be difficult. Therefore, their state of uncertainty about what decision to make is high. To model this, difficulty levels could be assigned to each task, or a group of tasks. This would indirectly indicate decision making uncertainty levels. The more difficult task would have a higher uncertainty index assigned as compared to an easy task. However, the index value should be weighed against expertise level; the same task, or group of tasks, should be represented by different values of the index for the expert as opposed to the novice or advanced beginner. This could allow one to infer about the time needed to perform a certain task under stress/combat conditions. For a cruder analysis, instead of concentrating on each task individually, tasks could be grouped according to MOS and each MOS could have an index assigned.

Furthermore, a cross analysis of uncertainty levels and decision correctness would permit modeling of all these factors for different "expertise" levels. Certain decision making time thresholds could be established beyond which decision making would be rendered ineffective for each expertise level.

5. DISCUSSION

Controversy and disagreement will continue regarding the integration of human factors into precise models. When the methods of measuring indirect effects of weapons and other "intangible" casualty mechanisms improve, there will still be deviations in the results because of individual differences and the surprising unpredictability of human behavior.

The traditional term "suppression", with its numerous definitions used in the military community at present, lacks consistency in describing the other-than-physical effects of weapons. To establish a more consistent and precise quantification measures for the non-physical effect of weapons, the term indirect effects of weapons is advocated to describe such combat effects.

In this report, all of the proposed submodels for indirect effects of weapons or non-physical incapacitation mechanisms are based on a certain assumed taxonomy of a combat system. Further real-life or experimental data need to be available to identify the exact relationships shown in the curves.

The specific solutions in the submodels are not meant to be inclusive or inherent to the particular submodel. They can be mutually adapted and used in other submodels. The proposed model (or submodels) can be further developed and modified to fit larger and existing models, especially those already addressing human performance degradation and personnel vulnerability factors.

Some of the important combat activities, such as maneuver or mobility were not addressed in this report. These activities relate to a unit's movement as opposed to the movement of an individual, which is the focus of all indirect effects submodels in this report. Therefore, for the sake of homogeneity in this model, this combat activity was excluded. Nevertheless, any impediment in movement of troops is a form of indirect effect; upon a temporary or permanent forced/unintended halt or slowing of movement caused by the enemy's near miss, the unit's mobility or maneuverability is compromised. Modeling predictions of weapons' indirect incapacitating effects on a unit movement are enormously complex as a result of the extreme number of variables involved. Movement recovery times would have to be considered for different unit types and sizes; various environmental, climatic, meteorological conditions; type and number of man-made obstacles; and other related variables contributing to movement speed. However, a "short-cut" in the form of the recovery times esta-

blished through a post hoc analysis of recovery time could be employed. Recovery time could be defined as the time interval needed to fully return to a non-affected functions status at state 0 prior to introduction of the near miss stimulus. If, for example, the affected unit scatters and takes cover, the recovery times might equal to the re-assembly times. These type of data can be collected via live unit exercises.

The understanding of indirect effects of combat weapons is critical in modeling the comprehensive effects of combat accurately and realistically. Indisputably, these allegedly "intangible" combat factors are not as predictable as the direct effects of weapons; however, they *can* be quantified. Even though some of the indirect effects obey non-parametric statistics, they are *not* unquantifiable. Therefore, general combat damage and casualty predictions should not only include the direct effects but also the weapons' indirect incapacitating effects on humans as combat technology operators.

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